Vol. X. NOVEMBER, 1893. No. 7.

THE AMERICAN METEOROLOGICAL JOURNAL.

A MONTHLY REVIEW OF METEOROLOGY.

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BOSTON, NEW YORK, CHICAGO, AND LONDON.

GINN & COMPANY,

Publication Office, 7-13 Tremont Place, Boston, Mass., U.S.A.

SINGLE COPIES . . 30 cents. | PER ANNUM $3.00

Entered at the Post-office, Boston, as second-class mail matter.

THE AMERICAN

METEOROLOGICAL JOURNAL.

VOL. X. BOSTON, MASS., NOVEMBER, 1893. No. 7.

A LOOP IN THE TRACK OF AN OCEAN STORM.

ENSIGN EVERETT HAYDEN, U. S. N.

[*From the Proceedings of the U. S. Naval Institute, Annapolis, Md.; Vol. XIX., No.* 3, 1893; *whole number* 67.]

A STORM-TRACK, as usually shown on weather maps and on the well-known Pilot Chart of the North Atlantic Ocean, published by the U. S. Hydrographic Office, represents the path of the centre of the storm; that is, of the point of lowest barometer. This point coincides, in the great majority of cases, with the centre of the whirling winds that make up the cyclone. Anyone who has had regular or even casual access to such publications must have noticed that storm-tracks are sometimes very irregular, and that occasionally an actual loop is represented. The question is often asked whether the facts justify such a track, and undisguised incredulity is sometimes expressed as to the possibility, or at least probability, of such erratic movements. In the case of storms that occur over the land, where regular observations are taken at numerous and well-selected stations, it is very easy to locate the storm-centre at frequent intervals of time and space, and thus, by joining such points in chronologic order, plot the storm-track with unquestionable accuracy. The fact is thus brought out very clearly that the tracks of land storms do often form loops. At sea, however, the data are often too few, or too poorly distributed, to allow of drawing the track with such accuracy, and this necessarily results in the elimination of whatever erratic tendencies the track may actually have been guilty. Occasionally, however, the data are so complete as to allow of a very accurate charting

of the storm-track, and it appears that the tracks of ocean storms do really occasionally form loops of this kind — as indeed might naturally be inferred by analogy and by *a priori* reasoning based on the general character and movements of such storms.

Upon the Pilot Chart for February, 1893, such a loop was shown in a storm-track west of the Irish Channel, and, question having arisen as to the correctness of my work, I went over the whole subject very carefully again, aided by data received after the Chart went to press, and prepared the following statement, which, proving as it does, in this particular case, a loop in the track of an ocean storm, may be regarded as worthy of study by all interested in the subject. The detailed reports that are appended should be referred to for confirmation of every statement and for the solution of any doubtful point that may arise, and I venture to say that no sailor will ever regret the time that may be required to follow the discussion through from beginning to end, studying not only each report explicitly referred to, but also those not so referred to, in order to verify, to his own entire satisfaction, the fact that the storm-track is correctly represented.

One other question that arose subsequently may well be referred to here, and that is, How does the law of storms apply in the case of such an abnormal track? My answer is that it applies exactly as well as in the case of any other storm. In other words, a vessel encountering the storm has certain shifts of wind and must be guided by the well-known rules for such shifts. In some positions relative to the track the wind may veer gradually from northeast to southeast, south, southwest and northwest. In other positions it may back from, say, southeast to northeast, north and northwest. In still others it may first veer through half a dozen points, then steady, and then back. In each case action must be taken, if possible, exactly as the rules prescribe for wind shifting to the right, or for a steady wind, or for a backing wind, and the navigator need not and will not bother his head as to whether the storm-track is describing a loop or even a figure of eight, so long as he is on the right tack according to the wind and the shifts of wind that he himself is experiencing.

The statement referred to is as follows: —

HYDROGRAPHIC OFFICE, WASHINGTON, D. C.
Feb. 9, 1893.

Sir, — In compliance with the Hydrographers' memorandum, referred to me by yourself yesterday, I beg to submit the following statement relative to the track of the storm of Jan. 3–9, '93, west of St. George's Channel.

The positions of the storm centre at Greenwich noon each day, are defined quite definitely on our synoptic charts, as indicated by the data regarding wind and barometer plotted thereon. The track is drawn from each of these positions to the next one, care being taken, of course, to examine the conditions as carefully as possible, so as to be sure the storm was continuous within the region and time under consideration. In the case of a storm of any decided severity we generally receive a number of storm reports, in addition to those for noon, G. M. T., and such reports often enable us to plot the track between the noon positions with great accuracy. But in some cases we have less complete information for that portion of the storm-track, and have, therefore, to rely upon our general knowledge as to the motions of storms under similar conditions. In the case now under consideration, the data were sufficiently complete to draw the track with considerable confidence, and later data (received during the past two weeks), confirm the track as drawn on the February Chart.

To illustrate the way in which the position of the storm centre is determined for noon, G. M. T., a copy of part of our synoptic chart for Jan. 3, 1893, is given herewith (Plate I.).

It will be seen at a glance that the wind-circulation as well as the distribution of barometric pressure locate the centre quite definitely at the position marked. Similarly, for each succeeding day the centre is located for the time of the chart (Greenwich noon), and the next step is to join these positions by a line that shall represent as accurately as possible the track that the storm centre followed from any one day to the next.

The second of the accompanying maps (Plate II.) gives the track of the storm from Jan. 2–4, inclusive, and the tracks and names of the vessels near the centre of the storm on the 3d and 4th, by means of whose reports the peculiar loop in the storm-track can be explained. The tracks of these vessels, it will be noticed, are from Greenwich noon of the 3d to Greenwich noon of the 4th in each case, or from about 10 A. M., local time, of the 3d, to 10 A. M. of the 4th. The tracks of the "Brazilian" and "La Hesbaye" are of special importance, inasmuch as these two vessels passed through or near the centre during the recurve.

Abstracts of the reports of each of the vessels, whose tracks are plotted on Plate II., are given herewith, and these data show that the storm centre moved as indicated, and that the track described a loop as the storm recurved from its position on the 3d to its position on the 4th. In a word, the storm approaching from the southward turned to the westward and followed close after "La Hesbaye" (which vessel had ESE. shifting to N. and NNE. winds), and then moved south and east completely around the

"Brazilian," which vessel was bound east and had the wind shifting from NE., to N., NW., W. by S., WSW., SW., S., S. by E., SSE., SE. No better instance could possibly be selected to illustrate such a case, and, indeed, these two vessels' reports are in themselves sufficient to prove that the storm-track did make a loop. The other reports, however, confirm it in every respect, and the plotted tracks show how complete the data are. An attentive examination of these data, moreover, shows them to be perfectly consistent and reliable.

The report of the "State of Nebraska" may be referred to further, as it shows that there was another and entirely distinct storm to the north of that vessel, a storm whose track cannot be plotted, for lack of data, but to whose influence the peculiar recurve of this southern storm was doubtless due. It is well-known that storms act in this way under just such circumstances, both at sea and over the land, and many good examples might be referred to. To select only two, take the case of the storm over Nova Scotia, March 5 and 6, 1892 (see April Pilot Chart), and the storm over the Bay of Biscay, Oct. 12–16, 1892 (see Pilot Chart for November). In each of these cases the facts are indisputable, and the present discussion is valuable as emphasizing an equally good instance of a loop in a storm-track at sea.

Very respectfully,

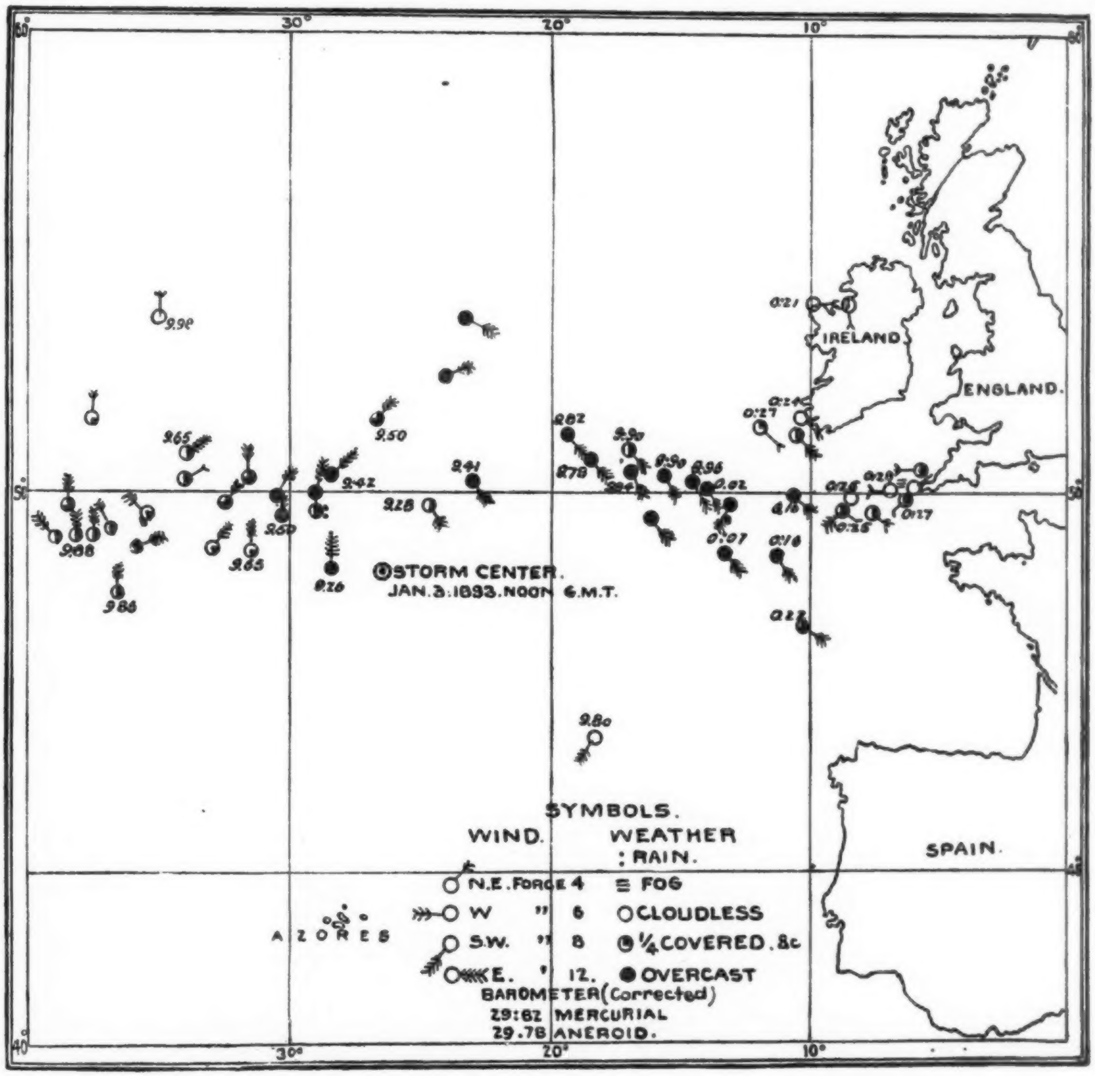
EVERETT HAYDEN,
Marine Meteorologist.

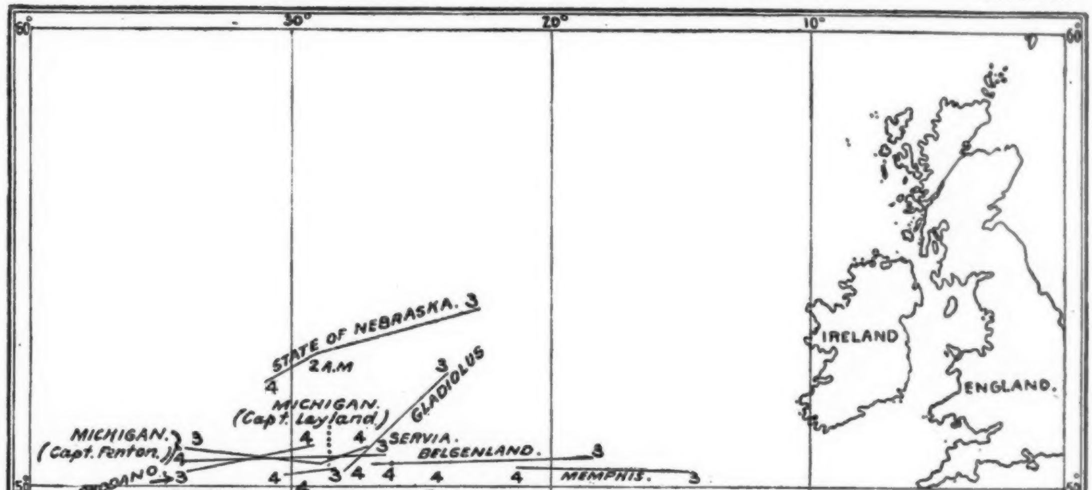
To the Chief of Division of Marine Meteorology.

ABSTRACTS OF REPORTS.

Belgenland (Bel. S. S.), Capt. Bence. Report by Fourth Officer Doncker. SE. wind, increasing, heavy rain squalls ; lowest bar. noon, 4th, 29.00 (aneroid, as read off), wind, SE. 8, shifting to NE.

Brazilian (Br. S. S.), Capt. Whyte. Report by Lewis Thompson, Second Officer. *Jan.* 3, A. M. — Squally, with rising sea, cloudy weather, wind remaining steady from N. to NNE. 8 A. M. — Wind increased to fresh gale, varying from NE. to N., with high confused sea. Noon. — Strong gale, gloomy, threatening weather, sea very high and cross. Wind about 4 P. M. changing from N. to NW. and W., moderating to fresh gale at 6 P. M. Wind then went to W. by S. 8 P. M. — Wind still moderating and shifting rapidly to WSW., SW. to S. Midnight. — Fresh breeze, S. by E., clear, with passing clouds, sea rough and confused. *Jan.* 4, A. M. — Wind following the above came from SSE. to SE., strong breeze, squally. Lowest barometer, Jan. 3, at 8 P. M., 29.20 (merc., corrected), remaining steady for 3 or 4 hours, rising toward midnight.


IRELAND
ENGLAND.
SPAIN.
AZORES
STORM CENTER.
JAN. 3. 1883. NOON G.M.T.
SYMBOLS.
WIND.
WEATHER
: RAIN.
N.E. FORCE 4
≡ FOG
W " 6
CLOUDLESS
S.W. " 8
1/4 COVERED. &c
E. " 12.
OVERCAST
BAROMETER (Corrected)
29:62 MERCURIAL
29.78 ANEROID.



STATE OF NEBRASKA. 3
2 A.M
4
GLADIOLUS
3
MICHIGAN.
(Capt. Leyland.)
MICHIGAN.
(Capt. Fenton.)
3
4
4
4
SERVIA.
BELGENLAND.
3
PRODANO
3
4
3
4
4
4
4
MEMPHIS.
3
BRAZILIAN.
3
4
3 LA HESBAYE
3
4
DIAMANT
4
3
STORM TRACK.
JAN. 2. 1893. NOON. G.M.T.
AZORES
IRELAND
ENGLAND.
SPAIN.
30°
20°
10°
60
50
40

The following is a more detailed report : —

Jan. 3, 9.59 A. M. — 49° 28′ N., 30° 16′ W., N. 7, 29.49, g. q. Fresh breeze since yesterday, wind increasing at midnight to strong NE. breeze. Cloudy ; later, fresh gale, squally ; gloomy and threatening weather, with high sea from NNE. Noon. — 49° 31′ N., 29° 08′ W., NNW. 9, 29.26, u. q. r.

(Form 105*b*), 8 P. M — 49° 35′ N., 27° 48′ W., W. by S. 5. 29.20, o. p.

(Form 105), 8 P. M. — 49° 30′ N., 28° W. (sic), W. by S., 29.20. Midnight. — 49° 43′ N., 26° 52′ W., S. by E. 5, 29.20, b. c.

Jan. 4, 10.22 A. M. — 49° 54′ N., 24° 35′ W., SSE. 6, 29.29. g. c. q. At noon yesterday, fresh gale, with high confused sea ; wind N., changing to NW. and W. ; at 4 P. M., strong gale. 6 P. M. — Weather moderating, wind W. to SW., shifting to S. ; clear weather. *Jan.* 4, A. M. — Wind freshening from SSE., stormy looking and squally ; short broken sea from SE. Between 4 and 8 P. M. — Wind shifted from S. through E. to NW., light breeze. *Jan.* 5, A. M. — Strong breeze, WSW. to SW. ; clear weather, wind changing to SSW., cloudy, bar. rising.

Diamant (Nor. S. S.), Capt. Kelterer. *Jan.* 3, 10.08 A. M. — N. 8, 29.55 (aneroid, as read off). Noon. — 49° 28′ N., 29° 26′ W., NNE. 8, 29.55 (aneroid, as read off). *Jan.* 4, 9.41 A. M. — NNW. 7, 29.92.

Gladiolus (Br. S. S.), Capt. Wright. *Jan.* 3, 10.20 A. M. — NE. 5, 29.72 (aneroid, as read off). *Jan.* 4, 10.08 A. M., N. by E. 9, 29.50.

La Hesbaye (Netherlands S. S.), Capt. Ninnes. Report by Chief Officer Eckhoff. *Jan.* 3, 10.21 A. M. — SSE. 5, 29.30 (aneroid, corrected). During part night very strong breeze, with rain showers, from ESE.; very high rolling sea from SSW. *Jan.* 4, 10.02 A. M. — N. to NNE. 9-10, 28.77. Foggy sky with light mist — showers during past night ; lowest bar., 28.71 (time and position not stated). *Jan.* 4, midnight. — Wind hauling to N'd.

Memphis (Br. S. S.), Capt. McNeely. Report by Second Officer Burgess. *Jan.* 3, 11.04 A. M. — SE. 7, 29.64 (aneroid, as read off). 3 P. M. — 50° 30′ N., 15° 30′ W., SE. 9, 29.26. *Jan.* 4, 10.36 A. M. — S. 6, 29.16. For past 24 hours, fresh gale, high confused sea, clearing towards noon.

Michigan (Br. S. S.), Capt. Fenton. Report by Fourth Officer Dix. Boston toward Liverpool. *Jan.* 3, 9.57 A. M. — NE. 8, 29.65 (aneroid, corrected). 4 P. M. — NE. by N. 6, 29.75. Midnight. — NNW. 10, 29.31. Fierce gale, overcast, high sea. *Jan.* 4, 4 A. M. — NW. 10, 29.30. Gale showing signs of abating; bar. stopped falling, sky clearer. 8 A. M. — Variable, 3, 29.36. Gale finished, blowing itself out, followed by variable winds, finally settling at ESE., and fine, clear weather. 10.12 A. M. — E. 3, 29.37. This gale commenced with first fall of bar., and increased rapidly, moderating when bar. stopped falling, weather clearing as bar. rose.

Michigan (Br. S. S.), Capt. Layland. Report by Third Officer Forsyth. Swansea toward Philadelphia. *Jan.* 3, 10.08 A. M. — NE. 7, 29.45 (aneroid, as read off). *Jan.* 4, 8 A. M. — 50° 29′ N., 29° 28′ W., NNE. 9, 29.25. 10 A. M. — NE. 9, 29.36.

Prodano (Br. S. S), Capt. Trotter. Report by Second Officer Fison. *Jan.* 3, 4 A. M. — Very heavy hail squall from N., lasting over half an hour. Then sky clear and winds variable, clouds from N'd. 10 A. M. — Light wind setting in from NNW., steadily increasing till 4 P. M., when it was blowing a fresh gale from NNW.; sea getting up very quickly and sky becoming overcast. From midnight till noon of the 6th(?) it blew a whole gale, with tremendous long rolling sea. 4 A. M. — N. 2, 29.81 (aneroid as read off). 5 A. M. ? — NNW. 5, 29.65. 6 A. M. — NNW. 11, 29.29. Noon. — NNW. 8, 29.36. 7 P. M. — NNW. 3, 29.47.

Servia (Br. S. S.), Capt. Dutton. Reported by Extra Second Officer Cleere. *Jan.* 3, 10.10 A. M. — NNE. 7, 29.50 (aneroid, corrected). *Jan.* 4, 9.41 A. M. — N. 7, 29.80. The gale commenced on the 3d at SE., veering to E., to NE., and N., finally NNW. (true), blowing hard between NE. and N. at 8 P. M. Continued to blow hard till 5 A. M., 4th, when wind and sea moderated sufficiently to keep ship on her course, she having been hauled up to the N'd of her course for about 12 hours (3 P. M. to 3 A. M.).

State of Nebraska (Br. S. S.), Capt. Brown. *Jan.* 2–3. — Light unsteady winds, shifting to SE. and increasing. *Jan.* 3, 10.27 A. M. — E. by S. 6, 29.83 (aneroid, as read off). *Jan.* 4, 2 A. M. — 53° 04′ N., 29° 10′ W., SW., 7, 29.23 (aneroid, as read off.). Wind shifted to NW. *Jan.* 4, 9.56 A. M. — N. 9, 29.43.

THE MECHANISM OF A TORNADO.

PROF. H. A. HAZEN.

THOSE interested in this subject will at once admit the great importance of its thorough demonstration, and also that it will be about the most difficult subject to fully elucidate in the whole science of meteorology. I have examined with care the plates prepared by the Weather Service for its reports and papers on tornadoes during the past twenty years. It is my hope at some future time to publish these in book form, together with other illustrations, in order to make them available to a larger circle of students; just at present, however, it is of great interest to make a special study of these plates in the line of the above topic. In addition to these plates, I have selected out for study all the earlier published illustrations, especially those giving the distribution of *débris*. Some may think that these earlier diagrams, made more than fifty years ago, have been entirely superseded by later and better charts, but quite the contrary is the truth. If anything, these earlier diagrams are better in most respects than the later, as they were made for the most part, at a time when there were the greatest doubts as to the mechanism of the tornado, and also they were made by some of the acutest observers that have studied the subject. The earlier labors and studies of Espy, Bache, Redfield, and Loomis have had no counterpart in these times, a half century later, and it is entirely safe to say that by far the best results can be obtained to-day from the researches of these thoroughly equipped and learned men.

After a careful study of all the charts showing the direction of fallen trees and the lines of *débris*, I find that some confusion has arisen from a lack of discriminating between the destruction on the right and on the left of the path. It is especially to be noted that the centre line of the path is not through the centre of the region of uniform destruction, but rather to the north or left of the centre, and at the intersection of the action on the right with that on the left. This was markedly the case in the Wimmerby, Sweden, tornado. See plate A 1 in *Meteorologische Zeitschrift*, for February, 1891, p. 80. A part of this plate is here reproduced, and an almost exactly parallel case is to be found at the South Lawrence, Mass., tornado, on July 26, 1890, in "United States Monthly Weather Review," for July, 1890. Making due allowance for this difficulty and also for tornado freaks, these diagrams bring out the following four points in the order of their prominence:—

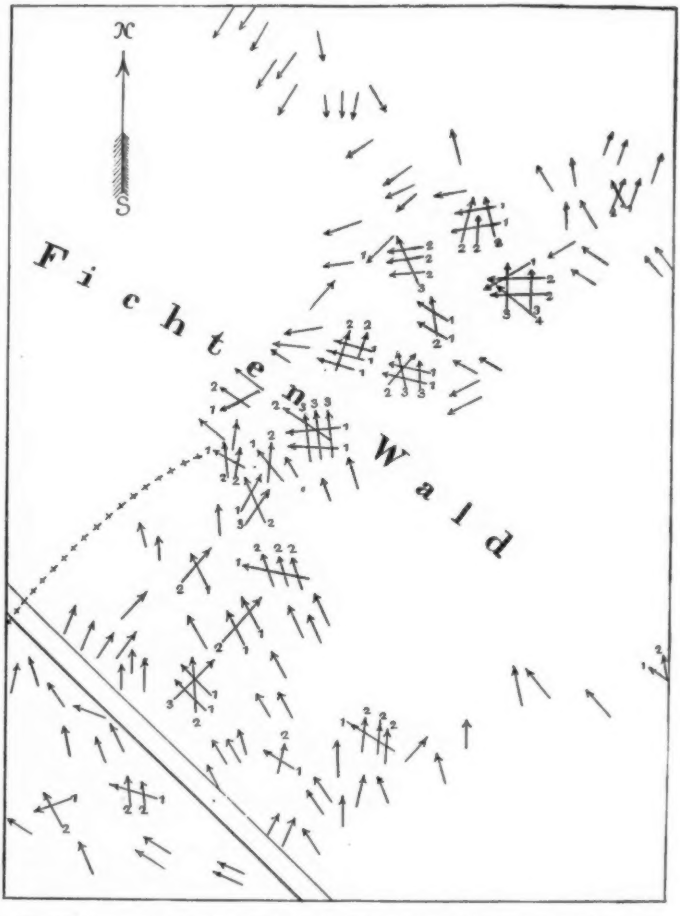
First. The tendency in all tornadoes is for trees and *débris* to lie either in the direction of the track, or else inclined slightly toward the track and forward in the line of its motion. This

tendency was admitted by the earlier observers of the phenomenon and even by those who, like Espy, believed there was an enormous fall in pressure in the tornado, and into this the air rushed with very great velocity from all sides. An illustration of this view will be found in "Philosophy of Storms" (Espy, p. 354, or in "The Tornado," p. 42). In order to account for the fact that trees pointed uniformly in the same direction after the storm, it was thought that the breaking down of the tree was at first backward as if sucked into the partial vacuum, and then the rear of the storm pushed it over so that it was inclined in the same direction as the track. This view would seem very unsatisfactory and would not account in any manner for the uniform position of the trees.

Second point. On the south or right hand side of the path there are apparent indrafts or regions of destruction for a much greater distance than on the left. This is brought out most clearly in the two cases already mentioned, and also in the New Brunswick, N. J., tornado of June 19, 1835. See diagram in "Am. Jour. Sci.," 1841, Vol. 41, p. 79.

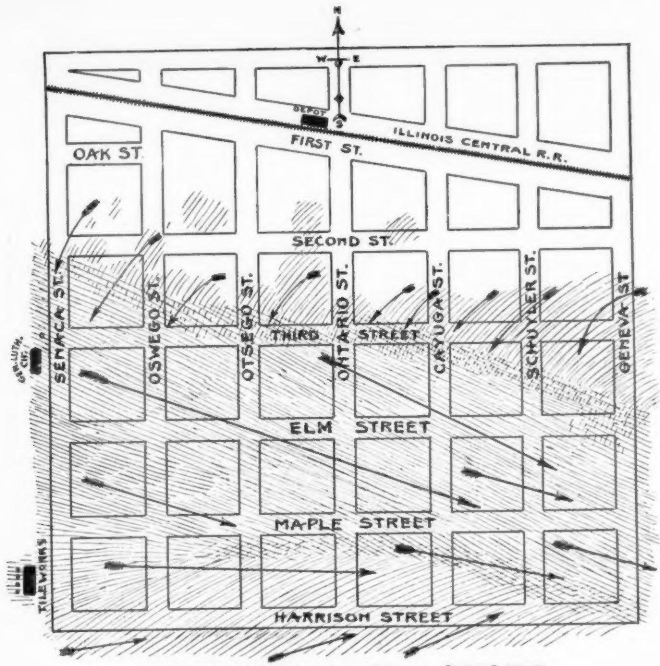
Third point. There are peculiar freaks of the tornado in which trees are piled one on top of the other in seeming great confusion, but in reality with the extremest uniformity. These cases are ordinarily on the right of the track. Prof. Loomis measured a very great number of such fallen trees, and indicates that they were on the left of the track. See Mayfield, Ohio tornado, "Am. Jour. Sci.," 1842, Vol. 43, p. 300. A careful study of his description, however, shows that these trees were really on the right of the track, and he was misled by the fact, already brought out, that the centre of action of the tornado is not at the centre of destruction. The singular thing about this phenomenon is that the bottom tree invariably points toward the track, the second tree points more in the direction of the track, and the third still farther around to the right, that is, these trees forming individual groups behave almost exactly as the single trees uniformly pointing toward the track on the right and left, and along the track in the centre. Prof. Loomis averaged all the trees he measured and found the bottom inclined n 55° w, second, n 16° e, and top n 62° e, the track of the storm was inclined n 33½ e. This would seem a most important line of investigation, and one that should be carefully studied. We need especially, just now, a few measurements of such tree falls on the left side of the track and at some distance from it. A good diagram giving these phenomena is that of the Wimmerby tornado reproduced here.

Fourth point, and the one most puzzling of all, is the occurrence of trees and *débris* pointing nearly at right angles to the direction of *débris* under the first head. It is believed that these trees and *débris* are almost invariably on the left of the

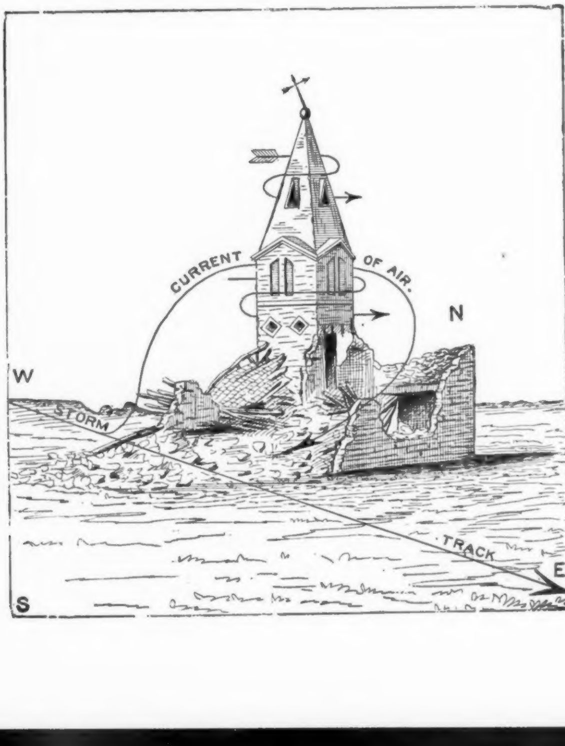


TORNADO THROUGH A FOREST OF FIRS AT WIMMERBY, SWEDEN, JULY 6, 1890.

NOTE. The line of crosses is on the original plate and shows the separation of right hand and left hand destruction.

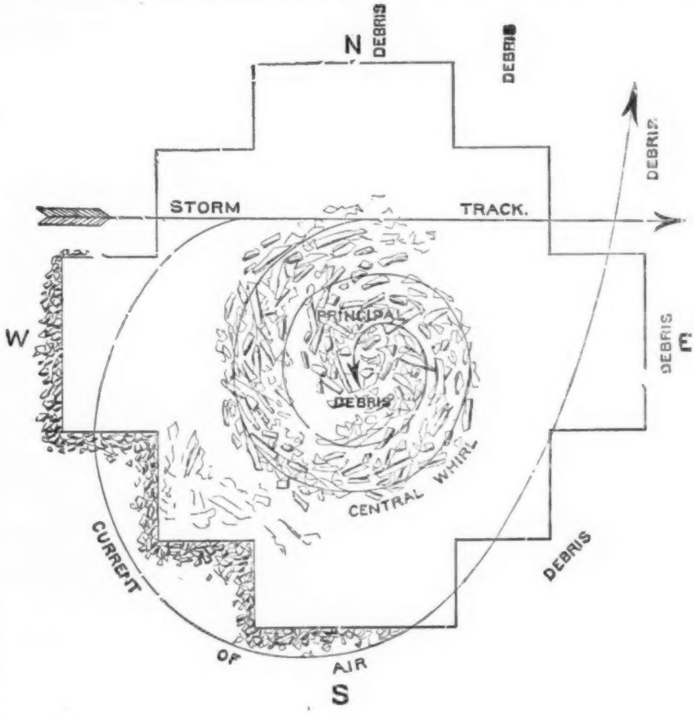


TORNADO AT POMEROY, IOWA, JULY 6, 1893



track, and their fall and position show that the blow which felled them was the first in the tornado and was a straight-line blow coming from the north or northeast. It is thought that these *débris* always lie under those lying in the direction of tornado, but this point demands most careful research. Perhaps the best illustration of this fourth point is to be found in the description of the Pomeroy, Iowa, tornado of July 6, 1893. The diagram will be found in the Iowa *Monthly Review* for July at page 6, and has been reproduced here. This diagram shows very clearly the first point here mentioned and also the fourth. I am still in correspondence with Mr. J. R. Sage, who made the original, and hope to gain farther information from him. I have also studied all the other diagrams of tornadoes and have found several parallel cases, notably at Wimmerby, at Providence, R. I., Aug. 30, 1838, and at New Brunswick mentioned above.

There is an explanation of this point, I think, in the phenomena of the clouds seen on either side of the tornado as it approaches the observer. It was thought for many years that the cold, northwest cloud met the warmer one from the south-



west and thereupon a terrific conflict ensued, ultimately resulting in the evolution of the tornado. Of course, it would be impossible for any serious disturbance to occur from the meeting of two clouds in a vertical plane, no matter what contrasts of temperature there might be. There is another fact which is very remarkable, and that is that all along the onward advance of the tornado these same clouds are seen, and this may be for one hundred miles. It is plain then that these clouds accompany the tornado and may be very important adjuncts when their functions are fully understood. Since this appearance is the first noted, it would seem entirely reasonable that the first destruction should be caused by the cloud at the outside, and, if this cloud has a tendency to move from the north or northeast, all the phenomena under the fourth head above could be readily explained. I hope that these notes will lead to fuller research. We wish to know a great deal more about this cloud. Is it separated from the general confused mass of clouds at the centre? Is it a continuous or an individual phenomenon? What becomes of the cloud after it disappears? In fact we should know in minute detail all the actions and movements of this cloud on the north side.

Without doubt many persons will be surprised that I have made no mention of the evidences of a whirl in the distribution of *débris* and the lay of trees. Careful study of all the diagrams does not show any evidence of a whirl three hundred or four hundred feet in diameter, nor any facts that cannot be explained by the hypothesis here suggested. The evidences of a whirl are to be found in the views and statements of persons who thought they could see the whirl in a vertical funnel-shaped cloud, but it is well understood that such evidence is practically valueless. The whole theory of a whirl is built up not from a study of *débris*, one of the best methods that could be asked for, but from confused statements of observers and from a preconceived opinion as to how a tornado is formed. A good proof of this confusion can be found in two sketches of buildings a few rods apart that were destroyed by the same tornado, found on pages 46 and 47 of Professional Paper, No. 4. In the sketch on the left hand page, the whirl, which is figured as having several convolutions, revolves from right to left or counter-clock-wise, while on the opposite page there are about as many convolutions in just the opposite direction.* I may add that Prof. E. H. S. Bailey, in "Science" for July 7, 1893, in describing the tornado at Williamstown, Kan., June 21, 1893, confirms some of the above views. He says, "The material north of the centre of the track was deposited in lines from northwest to southeast and that on the south side of the centre in lines running from southwest to northeast."

* These cuts are here reversed; the original right hand cut is here on the left.

HOT WINDS IN TEXAS.*

ALLEN BUELL, OBSERVER, WEATHER BUREAU.

IN an article recently published in this JOURNAL (Vol. IX., 437–443), an attempt is made to explain the cause of the "Hot Winds of Texas," the writer assuming that the air overlying a considerable area of country is, during certain seasons, heated "dynamically." That the free air may be made sensibly warmer by compression, agitation, friction, or any form of energy, is not denied, but the effect of heat so communicated is only temporary, that is, not constant, and could not be, from the fact that it is free to expand and contains more or less aqueous vapor. Temporary heat might be produced by compression, assisted by "overshoots," and by whirls which will be noted further on. Whether the assumption be true or false it is not, however, the purpose of this paper to discuss, but to state some facts in relation to the phenomena that have been ascertained by observation. These facts, studied in connection with the topography of the country, the soil, and the meteorological conditions existing at times during the hotter months of the year will, it is thought, suggest some explanation of the causes that produce hot winds which have properties that destroy some kinds of vegetation in some parts of Texas. The air over a considerable area may become hotter than the surrounding air, as we frequently find it over small areas, depending on the character and condition of the soil upon which the rays of the sun fall, and the state of the atmosphere through which they pass. Thus in extremely hot and dry weather vegetation is withered and burned up, so to speak, along the sides of a sandy road. The effects are not uniform, but exist in spots. Here and there vines are found black and lifeless while grass in the immediate vicinity is unharmed. Then again grass will be found withered while vines running over fences and clinging to trees near by are growing thriftily. An examination of the roots of plants, vines, etc., and of the soil where these anomalies exist, shows that it was not excessive heat alone that caused the withering.

* By permission of the Chief of the Weather Bureau.

Insufficient nourishment and the *sucking properties* of the dry air were the most potent agents in the work of destruction. Where the soil was somewhat damp and the roots deep in the ground no signs of withering were noticed. There was no evidence of hot air a few feet off the road. It must be, then, that a thin layer of air overlying a limited space like a country road has been, under favorable circumstances, super-heated and dried, so to speak. This undue heating produces undulations or conditions which induce whirls. Assuming that the heating of the surface air induces whirls, we may say that the heated air over a wide space is picked up, as it were, and concentrated in the whirl, whose temporary effects are seen here and there in the burned foliage of bushes. Similar effects are noticed in the path of wind blowing off fields of ploughed ground. In one instance it was found that the temperature of the wind coming off a sixty acre field of ploughed ground was from fifteen to twenty-five degrees in excess of the temperature of the air to the windward of the field and on either side of the field. There were hot blasts — vertical whirls — whose temperature was high enough to cause painful sensations of heat to the face and hands. The observations were made at 2 P. M. on a day of sunshine with the wind fresh southwest and the air comparatively dry. For a distance of two miles in the path of this wind plants and vines were withered and foliage of bushes burned.

In another instance the temperature of the air blowing off a bed of sand, some two miles long and half a mile or more in breadth, covered with a scanty growth of weeds and post oaks, was observed. The heat was more intense and extended farther, and the effects of whirls and rolls were more numerous. The foliage of oak trees was in some places burned to a crisp, while the leaves of the mesquite were not injured in the least.

The soil in this part of Texas is largely of sand and clay with sand beds small in extent here, but of vast dimensions farther west. These plains of sand and clay under the pitiless rays of the sun, unobstructed by moisture, are, during the summer months, intensely heated. Owing to different conditions of soil and the character of vegetation covering them, differences of temperature arise. The air in contact becomes excessively warm and dry. At first the stratum of super-heated air is shal-

low, but with days of sunshine and sluggish movement it grows deeper, and on account of variations in density and consequently pressure this super-heated stratum is, sooner or later, set in motion. At this stage vertical and horizontal whirls commence playing, their burning effects showing in the foliage of bushes and trees. These effects are not uniform but exist in streaks and in spots, owing no doubt to the varied conditions and character of the country, in respect to the soil and vegetation, over which the hot winds blow, and the length of time they continue westerly; for, be it understood, westerly winds are the "hot winds of Texas." A fact connected with the phenomena which seems not to have been noticed is that foreign plants, vines, etc., are sometimes destroyed, while those native to the soil escape harm.

The preceding has reference to the ordinary hot winds likely to occur under favorable circumstances from April to October. The more destructive winds are felt from about the 20th of May to the 20th of July. Such winds occur only when certain meteorological conditions exist. They follow showery periods. They are dry and extremely hot. During the period referred to there is a tendency to the developing of storm areas which drift sluggishly eastward. Sometimes they remain stationary several days in succession. In the meantime the earth becomes extremely hot. Showers, instead of cooling the air and soil, add fuel to the flame, the water precipitated being converted by the heat of the ground into a hot vapor, and this, too, without lowering the temperature of the air or soil to any extent. To be sure there is sometimes a slight cooling of the air in the immediate vicinity of the shower, but the effect is short lived. The moist earth bakes, forming a crust, the nature of which reflects a greater part of the incident rays of the sun which are now "burning hot." Slowly the wind veers westerly, blowing off the fiery sand-beds of West Texas where lie accumulations of heat-energy seeking to escape. Finding an opening it rushes out with the force and heat of a furnace-blast. Sweeping over a country in a condition to radiate and reflect a great amount of heat, it gains rather than loses energy, and mingling with air already hot and dry carries destruction in its path. Where vegetation is luxuriant and the ground damp the effect is less noticeable than where it is scanty, shallow of root, and

the soil comparatively dry. Crops suffer most because on ground recently broken.

On account of the sluggish movement of the storm areas which linger day after day in the Missouri Valley, we will say for example, westerly winds continue, and may last a week or more, but their withering properties grow less and less from day to day as their force diminishes. They finally cease, being replaced by northerly winds of lower temperature.

The air is heated, to some extent, in a manner not before mentioned, and that is by innumerable reflections from water which may have collected in shallow pools, buffalo wallows, and foot holes. During the day this water is heated until its temperature is far in excess of the temperature of the overlying stratum of air. After the sun's rays have been withdrawn it cools and gives up its heat to the air and thus a high temperature is maintained at night.

"Overshoots" may prevent the escape of heat, and descending currents may produce heat "dynamically," and thus cause abnormal temperatures, but no harm comes from them. It is only when the air is in motion that we see its withering and burning effects.

The subject of "overshoots" and "overflows" will be discussed in a paper on "Northers" or "Cold-Waves."

Abilene, Texas, May 18, 1893.

MOUNTAINS AS STORM-BREEDERS.

R. De C. Ward.

In the July number of this Journal, Dr. T. W. Harris has an article on "Mountains as Storm-Breeders," in which he describes the formation of clouds over the Catskill Mountains in New York State, and the development of thunderstorms from these clouds, as the latter drift eastward over the Hudson valley. Dr. Harris notes that the clouds begin to form as small wisps over the mountains about nine o'clock in the morning; that they become larger and more numerous as the morning wears on; and that as they drift eastward over the valley of the Hudson

they usually melt away. About noon these clouds are described as becoming more numerous, and between two and four o'clock in the afternoon small thunderstorms are noted as being developed over the valley from some of them. The origin of the latter over the mountains leads Dr. Harris to the conclusion that the mountains have some decided control over the development of the thunderstorms of the region.

In presenting a criticism of a few points in Dr. Harris's article, the writer of this paper cannot speak from personal observation of the cloud and thunderstorm formation of the Catskills and of the Hudson valley, but from Dr. Harris's statements he believes that the case is not quite as that gentleman has stated it; in other words, that it is not the mountains which are the storm-breeders, but the valley. The formation of clouds over mountain tops and mountain ranges in the morning hours of fine summer weather is a well-known fact, and one which has been observed in many countries. It is due to the warming of the valleys and of the air lying in them, and the consequent ascent of the warmed air, which flows up the mountain sides. In so doing the ascending air may be sufficiently cooled to become cloudy, and the clouds thus formed will be noted at the heads of the valleys, or around the mountain summits. In the tropics, where these day or up-stream winds are best developed, this cloud formation often results in heavy rains or thunderstorms during the afternoon, and in our latitude, under favorable conditions, rains may also result from these clouds. It is noted, however, that these rains generally fall on the mountains and not over the lower-lying country around them. From Dr. Harris's account we learn that the clouds noted by him at Catskill rapidly increased in volume as they drifted across the Hudson valley, and that the thunderstorms were not developed until the clouds were over the valley. This seems to show that it is the valley that is the storm-breeder, rather than the mountains, although the latter may assist in the work to a certain degree.

In the present writer's investigation of the phenomena of the thunderstorms of New England, he has been struck with the fact that many of the thunderstorms of local origin, *i. e.*, which begin in New England, and do not come to that district ready-made from further west, have their origin in the valley of

the Connecticut River, which corresponds quite closely to that of the Hudson in New York State. The Connecticut River valley is a depression of some five to fifteen miles wide, extending from north to south across the region, and it has been often noted that in the early afternoon hours small thunderstorms develop in this valley and move off to the eastward in the usual fashion of such storms. There are many cases on record where thunderstorms which were only noted as scattering reports west of the Connecticut River valley seemed to gain in intensity as they crossed the valley. The reason for the development of thunderstorms over such broad valleys as those of the Hudson and the Connecticut seems to be plain. In them, there is a broad, more or less level expanse of surface, over which the air is lying in a relatively quiet condition, and where it may be easily warmed by contact with the warm ground in the morning hours. The valley being broad, there is very little chance for the warmed air to flow up the sides of the enclosing higher ground, and the result is, therefore, an ascent over the central parts of the valley, and the development of thunderstorms if the convectional overturning is sufficiently energetic. In the case of narrow and steep-sided valleys the diurnal warming tends to cause the day, or up-stream, winds noted above, there being no broad flat areas over which the warming air can lie. These winds blow up the mountain sides and may cause clouds, and, if well-developed, may produce rains. Such rains are, however, first noted on the mountains, as has just been stated, and not over the lower country near by, as in the case mentioned by Dr. Harris.

The evident control which the valley of the Connecticut exerts over the formation of local thunderstorms in New England has led the writer to believe that the Hudson River valley may be the seat of origin of many of the thunderstorms which come to New England ready-made from further west, and Dr. Harris's statements as to the formation of storms in that valley would seem to bear out this view. Hitherto, with only the records from New England to study, it has been impossible to determine much as to the place of origin of the thunderstorms of New England, most of which come from New York or further west. With the records from New York State, and from the other States to the west, which were collected during the summer of

1892, and during the past summer, it will now be possible to reach some definite conclusions as to this matter. The writer believes that such a study will reveal the fact that many of the storms which reach New England have their origin in the valley of the Hudson, and that others will be found to come across the Catskills from further west.

HARVARD COLLEGE, Oct. 1, 1893.

CURRENT NOTES.

The Meteorological Congress held at Chicago, Aug. 21–24, 1893. — Monday, Aug. 21, at 10 A. M., the Congresses of the Department of Science and Philosophy, of the Congress Auxiliary of the Columbian Exposition, were formally opened at the Memorial Art Institute of Chicago with an address of welcome by the President, Mr. C. C. Bonney, followed by responses from representatives of the various special congresses. At the close of this general session, the different divisions met in rooms assigned to them, the Division of Meteorology, Climatology, and Terrestrial Magnetism meeting in room xxxi., in which the regular sessions were held daily from 10 A. M. to 2 P. M., from Aug. 21 to Aug. 24.

The chairman of the congress not being able to be present in person the first day, Prof. F. H. Bigelow, representing Prof. Mark W. Harrington, opened the session at 11 A. M. of the 21st with a few words of welcome and a statement of the objects of the congress.

The congress had no legislative authority. The main purpose, as previously announced, was to collect together a series of memoirs "outlining the progress and summarizing the present state of our knowledge of the subjects treated," and to print them in full in the English language.

The meetings, while thus making the reading and discussion of papers a matter of secondary importance, were by no means lacking in interest or profit to those who were present. But few of the papers could be read in full owing to their great number and the absence of many of the authors. In all, about one hundred and thirty papers were read by title, in abstract or in full, forming a most valuable collection of memoirs prepared by writers of authority in their respective lines of research.

Among so many papers of merit, a simple list of which would occupy several pages, individual mention cannot be fairly attempted.

While the papers were read in general session, they were assigned, in the printed program, to various sections according to the subject, each section being placed in charge of a responsible chairman.

Section A. — Prof. C. A. Schott, U. S. Coast Survey, and Mr. H. H. Clayton, U. S. Weather Bureau, Chairmen. The papers of this section are devoted to instruments, their history and relative merits, and to methods of observation, especially to methods of observing in the upper atmosphere.

Section B. — Prof. Cleveland Abbe, U. S. Weather Bureau, Chairman. This section is the most extensive in its scope, dealing mostly with questions in dynamic meteorology; much attention is given to the study of thunderstorm phenomena in various countries.

Section C. — Prof. F. E. Nipher, Washington University, Chairman, comprises a series of sketches of the climate of different portions of the globe.

Section D. — Major H. H. C. Dunwoody, U. S. Army, Chairman, is devoted to the discussion of the relation of the various climatic elements to plant and animal life.

Section E. — Lieut. W. H. Beehler, U. S. Hydrographic Office, Chairman, deals with questions relating to marine meteorology, particularly to ocean storms and their prediction, methods of observation at sea, and international co-operation. During the reading of a paper on the work of the Hydrographic Office of the Navy, Lieut. Beehler had on exhibition a fine bust of Lieut. Maury, by the sculptor Valentine, of Richmond, Va.

Section F. — Prof. Charles Carpmael, Director of the Canadian Meteorological Service, and Mr. A. Lawrence Rotch, Director of the Blue Hill Observatory, Chairmen, comprises papers relating to the improvement of weather services and especially to the progress of weather forecasting.

Section G. — Prof. F. H. Bigelow, U. S. Weather Bureau, Chairman, deals with problems of atmospheric electricity and terrestrial magnetism and their cosmical relations.

Section H. — Prof. Thomas Russell, of the U. S. Lake Survey, Chairman, has to do with rivers and the prediction of floods.

Section I. — Oliver L. Fassig, Librarian U. S. Weather Bureau, Chairman, is devoted to historical papers and to bibliography, with special reference to the history of meteorology in the United States.

Prof. Mark W. Harrington, Prof. F. H. Bigelow, Capt. P. Pinheiro, of Rio Janeiro, and Lieut. W. H. Beehler, successively presided over the meetings. The printed program distributed at sessions of the congress contains a list of all papers presented; copies of this may be obtained from the secretary upon application.

At the close of the last session a resolution was offered calling for recommendations by the congress relating to (*a*) international co-operation in observations of auroras; (*b*) simultaneous Greenwich noon observations daily at all stations on land and sea, in addition to observations at other times; (*c*) investigation of the earth's magnetic polar current and the exact determination of the solar rotation. As the Congress had no legislative authority, it was agreed to hold a special session for the consideration of these questions after adjournment, on the following day.

Preparations have been begun for the printing of the papers, and an effort will be made to complete the work at an early date.

OLIVER L. FASSIG, *Secretary.*

WASHINGTON, D. C.,
U. S. WEATHER BUREAU, Sept. 15, 1893.

Annual Meeting of the American Association of State Weather Services. — The annual meeting of this body was held at the Art Palace in Chicago, Ill., on Aug. 21-23, 1893, with the following members in attendance: Prof. Mark W. Harrington; Messrs. Clark, of Arkansas; Craig, of Illinois; Sage and Chappel, of Iowa; Jennings, of Kansas; Burke, of Kentucky; Kerkam, of Louisiana; Hyatt, of Mississippi; Evans and Conger, of Michigan; McNally, of Missouri; Loveland, of Nebraska; Turner, of New York; Strong, of Ohio; Widmeyer, of Oklahoma; Pague, of Oregon; Ball, of Penn-

sylvania; Harmon, of South Carolina; Doherty, of South Dakota; Salisbury, of Utah; Ryker, of Virginia, and Moore of Wisconsin, with Wilson, of Tennessee, Clayton, of New England, and Frankenfield, of Illinois, as visitors.

The several topics discussed were: —

1. Inspection of stations of observation and display stations annually, to form the acquaintance of the observers and display men, and to instruct and encourage them in their work.

 (*a.*) Importance of location of instruments, and elevation of instrument shelter above ground.

 (*b.*) Instruments and shelter to be supplied by the Weather Bureau.

2. The necessity of sufficient weather-crop correspondents to make the data in weekly weather-crop bulletins thoroughly reliable.

 (*a.*) Time of day of issue of the weekly bulletins; should they not be issued Tuesday afternoon, and is it not advisable to manifold sufficient copies for the press of the State by means of the milliograph process?

 (*b.*) The best method of printing the weekly bulletin, and at whose expense.

3. Uniformity in method and class of data published weekly and monthly.

4. Importance of directors and assistants in charge making a special study of the crops grown in the State. Since the majority of States have experimental stations, and these stations are also voluntary stations, should not the date of inspection of such stations be prolonged to several days so as to give the student time to learn the important details connected with the growth of the several crops, etc.

5. Value of an annual convention of the voluntary observers, displaymen, and weather-crop correspondents in each State — some State fair day or at such time when the people of the State are drawn together.

6. Is the work of the director or assistant in charge of a State service of such magnitude as to make his duties as Local Forecast Official or Observer in charge of station too onerous to give him the time to do as well for his service as he could do if he had only the duties of director?

7. Relation of State Weather Services to experimental stations and what will improve them.

8. The necessity for more accurate measurement of snowfall.

9. The value of frost predictions and the best method of making them locally.

10. Methods of protecting tender crops from frost.

The resolutions adopted covering a number of the topics discussed were as follows: —

Resolved, That it is the sense of this Convention that a sufficient sum of money be appropriated annually by the National Weather Bureau to defray the expense of an annual inspection of all stations of each State Weather Service.

That the elevation of bottom of instrument shelters should be four and a half feet above the ground ; experiments made during the past year proving this elevation to give the best practical results.

That instruments and shelters should be supplied to voluntary stations by the United States Weather Bureau, and that when so supplied the installation should be done by the director or assistant director ; and that the necessary expenses of such establishment of stations should be paid by the National Service ; said establishment being considered a part of the annual inspection of voluntary stations.

That it is the sense of this meeting that the number of crop correspondents in the various States and Territories be left to the judgment of the Directors of said services ; but it is desirable that a sufficient number (one hundred or more) should be obtained to give accurate crop conditions.

That it is the sense of this Convention that authority should be given to Directors of State Services to issue and mail weekly Crop Bulletins on Monday evenings, where in their judgment a wider dissemination could thereby be secured.

That the National Weather Bureau should provide for the printing of the weekly weather crop bulletins in those States and Territories that do not provide for such printing.

That the State Director should, by visiting the Experimental Stations, thoroughly familiarize himself with the cultivation of crops which are especial features of his State.

That the State Services are so differently constituted, that it would be impracticable to apply the same rules to all ; that the local exigencies of each case should determine whether the Local Forecast Official and Director should be one and the same person.

That the method of sending forecasts daily is the most satisfactory to the public, and that the present method of sending them only when marked changes are expected, should be discontinued at the earliest practicable time.

The interest manifested throughout the sessions, and the advantages reaped by holding the Convention at the same time and place as the Meteorological Congress, cannot fail of seeing better work performed by the several services during the coming year.

A number of voluntary observers of the several State Services were in attendance.

The following officers were elected for the ensuing year : —

President, Major H. H. C. Dunwoody, Assistant Chief of the Weather Bureau.

First Vice-President, Mr. F. H. Clarke, of Arkansas.

Second Vice-President, Mr. Frank Burke, of Kentucky.

Secretary, Mr. James Berry, Chief of S. W. S. Division, Weather Bureau.

Treasurer, Mr. Geo. N. Salisbury, of Utah.

Executive Committee, Messrs. H. L. Ball, of Pennsylvania, N. B. Conger, of Michigan, and T. B. Jennings, of Kansas.

The convention adjourned to meet next year.

ROBERT E. KERKAM, *Secretary*.

List of Papers read in Section F of the Chicago Congress of Meteorology. — In the September number of this JOURNAL, pages 222–229, was published a list of the papers read at the Congress of Meteorology, Climatology, and Terrestrial Magnetism, held in Chicago, in August. The program was not complete at the time of going to press, and, in consequence, the titles of papers presented in Section F were omitted. In order to make the list as published in the JOURNAL a complete one, the titles of these papers are printed in the present number of the JOURNAL.

Section F.

WEATHER SERVICES.

PROF. CHARLES CARPMAEL (Director Canadian Meteorological Service, Toronto), Chairman.

First Session.

1. What Specific Additional Stations are Desired for Meteorological and for Climatological Purposes? Should the Publication of Climatic Data be for Places or Districts as Represented by Places?
   Prof. Dr. Julius Hann, Vienna, Austria.

2. Style of Official Publications and Arrangement of Data. What should be Published on Daily Weather Maps? What should be the Size of Maps? What Bulletins should be Issued?
   R. H. Scott, London, England.

3. Functions of State Weather Services.
   Major H. H. C. Dunwoody, Washington, D. C.

*4. What is the State of Our Knowledge as to Methods of Predicting the Development and Progress of Areas of Low Pressure and High Pressure?
   M. L. Teisserenc de Bort, Paris, France.

Second Session.

5. The Prediction of Dry and Rainy Seasons.
   John Eliot, M. A., Calcutta, India.

6. The Degree of Accuracy at Present Attained in Various Countries in Predictions One, Two, or Three Days in Advance. In Predictions What Elements of Weather is it Advisable to Predict?
   Prof. Dr. W. J. Van Bebber, Hamburg, Germany.

7. The Best Method for Testing Weather Predictions.
   Prof. Dr. W. Koeppen, Hamburg, Germany.

* Papers not received.

8. What is the Accuracy at Present Attained in Various Countries in Predictions as to Cold Waves and Injurious Frosts, One, Two, or Three Days in Advance? What Principles are Adopted in Such Predictions, and what Line of Work or Study Promises to Increase their Accuracy?
M. A. Angot, Paris, France.

Third Session.

9. Would it be a Good Plan to have Three Selected Stations make Automatic Record of Thunder, and an Automatic Record of the Induction Effect of the Electric Discharge, with a View to Determining the Energy of a Flash of Lightning?
A. McAdie, M. A., Washington, D. C.

*10. International Cipher Code for Correspondence Regarding Great Cyclones, Great "Highs," etc.
M. L. Teisserenc de Bort, Paris, France.

11. International Cipher Code for Correspondence Regarding Auroras and Magnetic Disturbances.
Dr. M. A. Veeder, Lyons, N. Y.

12. The Utilization of Cloud Observations in Local and General Weather Predictions.
Alexander McAdie, M. A., Washington, D. C.

Fourth Session.

13. What is the Accuracy at Present Attained in Various Countries in Predictions as to Thunderstorms and Tornadoes, One, Two, or Three Days in Advance? Is it advisable to Institute a Comprehensive Scheme of Thunderstorm Observation? Use of Telephone for Distant Thunderstorm Observations.
Dr. R. Billwiller, Zürich, Switzerland.

14. What Scheme or Plan for River Flood Predictions can be suggested?
M. Babinet, C. E., Paris, France.

The Effect of the Tide on Land and Sea Breezes. — Some interesting notes on the effect of the tide on land and sea breezes are found in Dr. Otto Krümmel's recent publication on "*Geophysikalische Beobachtungen der Plankton Expedition*" (Kiel and Leipzig, 1893). The Plankton Expedition was a scientific exploring voyage made on the Atlantic during July-November, 1889, which Dr. Krümmel accompanied in order to take meteorological and other observations, and the present volume contains the results of his work. With regard to the relation between the tide and the sea breeze, Dr. Krümmel noted, while at Para, that the latter was most marked when there was a flood tide. In several cases when the tide was low in the afternoon, the northeast Trades, which are the prevailing winds there and with which the sea breeze combines, were very light, but very soon after the tide turned and became flood, the on-shore wind increased in velocity and lasted until sunset.

* Papers not received.

This relation between tide and sea breeze Dr. Krümmel finds mentioned by several previous writers, among them Staff Commander James Penn, in his "Sailing Directions for the West Coasts of France, Spain, and Portugal" (London, 1867, p. 273). In speaking of the sea breeze at Cadiz that writer says: "The sea breeze set in most commonly with the flood." The commander of the German cruiser, "Habicht," notes in the *Annalen der Hydrographie* for 1887, p. 164, that at Cameroon the sea breeze is strongest with an afternoon flood tide, and Varenius, in his *Geographia generalis* (1650, 434), makes a similar statement ("*Testatur experientia, quod in illis locis, ubi fluxus et refluxus maris sentitur, si quando aër ab aliis ventis liber est, plerumque cum affluente aqua ex mari etiam ventus ex mari spiret*").

The greater velocity of the sea breeze over that of the inflowing tide shows that this fact cannot be due to the transportation, by the latter, of the air lying on top of the water. It can also not be due to the friction of the air on the water and a consequent movement of the air in contact with the water towards the shore. The sea breeze is due, as is well known, to the greater warming of the land by the sun's rays than the water, and the consequent greater warming of the air in contact with the land than of that lying over the water. This results in an expansion of the air over the land, a deformation of the isobars, and a circulation of air from land to sea aloft and from sea to land below. The effect of the tide on the sea breeze is due to the mechanical raising of the air lying over the water near the shore by the rising tide, and the consequent greater deformation of the isobars, which necessarily results in strengthening the circulation.

The effects of the occurrence of the flood tide at different times are many. When, for instance, it is low tide at 10 A. M., the tide runs in until 4 P. M., and therefore strengthens the sea breeze during those hours. From 4 till 11 P. M., the tide is running out, and from 11 P. M. till 5 A. M. it comes in again. This flood tide in the early morning hours prevents the contraction of the isobars over the land, and so interferes with the full development of the land breeze until after 5 A. M., when the tide is ebb, and then the land breeze suddenly freshens. A careful investigation of the phenomena of land and sea breezes with the times of high and low water in mind would doubtless bring out many interesting facts in this connection. The work could be easily undertaken by anyone living at the sea-side, at slight expense, and without the use of instruments of any kind.

CORRESPONDENCE.

THE THEORY OF CYCLONES.

Editor of the American Meteorological Journal:

Mr. Clayton's article on "Movements of the Air at all Heights in Cyclones and Anti-cyclones," in the JOURNAL for August, contains the following statement, on which I desire to offer a brief comment: —

"These diagrams show very clearly the inward movement of the lower air [in cyclones], with the outward movement above; and the reverse for anti-cyclones. There is, however, a curious difference between the cyclones and anti-cyclones in the fact that the cyclones preserve in general the same direction of rotation above as below, while in the anti-cyclone the direction of rotation has become partially or entirely reversed. The writer interprets this to mean that in cyclones the air is carried out against the gradient by dynamic action; for if the outflow of air were due to a gradient, the air would be deflected by the earth's rotation, as Ferrel has clearly shown, and there would be an anti-cyclonic motion above." (P. 177.)

I understand Mr. Clayton to imply by this that his results may be taken as a means of deciding between the two theories regarding the origin of cyclones at present in discussion; namely, the theory of spontaneous convectional action, whose leading advocate was Ferrel, and the theory that explains cyclones as passive driven disturbances in the general circulation of the atmosphere, recently brought prominently forward by Dr. Hann. Meteorology is fortunate in having so entertaining a problem as this to work upon, and fortunate also in its having excited so small a share of polemical discussion, the age of which I should like to think has passed.

It does not appear to me, however, that Mr. Clayton's excellent studies are demonstrative in the way he suggests for the following reasons: —

A simple convectional storm on a non-rotating earth would have concave isobaric surfaces below and convex isobaric surfaces above; its circulation would be maintained on radial lines, with inflow below and outflow above, the two separated by a neutral plane of no gradient. But as soon as the effect of the earth's rotation is introduced, such a convectional circulation is greatly modified, just as the general circulation of the atmosphere between equator and poles is modified by the introduction of this essential condition. The attitude of the isobaric surfaces is then determined not only by the differences of temperature, but also by the movements excited by these differences of temperature. In a warm-centred convectional cyclone on the actual earth, the isobaric surfaces would still diverge towards the axis of the storm; but we should expect to find most or all of the upper isobaric surfaces concave, with centripetal gradients; there the air would whirl out-

wards in a cyclonic or left-handed spiral (in our hemisphere) in virtue of the excessive centrifugal forces resulting from the high velocities that were gained on the even steeper centripetal gradients in the lower part of the storm. It would be only in the outer part of the storm that the upper gradients could be directed away from the storm-centre; and only there, even in a spontaneous convectional cyclone, could an anti-cyclonic or right-handed curvature of the winds be found.

The case of the general circulation of the atmosphere, which is undoubtedly a spontaneous convectional movement, presents a cyclonic outflow against the gradients, closely analogous to the left-handed outflow in the upper part of cyclones indicated in Mr. Clayton's figures. The overflow of warmed and expanded equatorial air approaches the north pole in a great left-handed whirl, and the return underflow towards the equator, against the gradients, also swings around the pole from right to left, until entering the trade-wind latitudes. The older theories failed to recognize this, and conceived the underflow from pole to equator as a northeast current; that is, as following a right-handed or anti-cyclonic curvature; but this view now finds no support either in observation or theory.

It therefore appears that the outflowing left-handed spiral in the upper part of cyclones, indicated by Mr. Clayton's results, is as accordant with the consequences of the theory of convectional cyclones, as with those of the theory of driven cyclones. The difference between the two can be detected only by precise quantitative measurement of temperatures as well as of cloud movements; and even with the aid of balloons this will be a matter of great difficulty. At present, the observations on the Sonnblick, discussed by Dr. Hann, and the great fact that the cyclones and anti-cyclones of the temperate zones are more active in the winter season, must be taken as favoring the newer rather than the older theory; although the manner in which driven cyclones are produced and maintained is still a matter for much study.

In this connection, mention may be made of a statement by Prof. Abbe in his excellent "Memoir of Ferrel," read before the National Academy, in April, 1892, and published in its proceedings. It is there said in effect that Ferrel had long ago investigated the effect of the general circulation of the atmosphere in producing cyclones and had laid it aside as of minor importance. "The so-called 'new views' had all been considered by him twenty years ago." (Pp. 284, 285.) Now, while I most warmly share with Prof. Abbe a high respect and admiration for Ferrel's work, it seems to me that this attributes too much to him. Ferrel's theory of the general circulation of the atmosphere truly opened a new era for meteorology, but his discussion of it included an essentially symmetrical circulation, in which the irregular eddying caused by unequal poleward gradients of temperature and moisture, by the inequality of land surfaces, and by the undulations of the atmosphere in consequence of its motion, received small consideration. These and other causes of uneven motion may have been considered and laid aside as negligable; but if so, the more recent studies of cyclones and of atmospheric undulations would indicate that it was a mistake thus to lay them aside.

I believe with Prof. Abbe that Ferrel's "mechanics of the general currents of the air and of the motions within [convectional] cyclones and tornadoes will undoubtedly stand the criticism of future times." The convectional cyclones of the torrid zone have their secrets laid bare by Ferrel's analysis, as the plans of the greater cyclonic movements of the whole atmosphere and of the smaller whirls of tornadoes are revealed to us by his genius; but this does not, to my view of the problem, exclude the possibility of driven cyclones any more than it excludes the possibility of driven wind eddies at street corners. It may possibly be true, in spite of the low temperatures, on the Sonnblick in cyclones and in spite of the greater activity of our cyclones in winter, that there are no such things as driven cyclones; but I believe that the proof of that proposition lies in the future and not in the past. W. M. DAVIS.

HARVARD COLLEGE, CAMBRIDGE, MASS., Sept., 1893.

Editor of the American Meteorological Journal:

Prof. Davis is so much better versed in the theory of cyclones than myself that I hesitate to differ with him in a matter of this kind; yet I find it difficult to believe that the course of the upper currents, whose direction and velocity must be closely bound up with the distribution of pressure, cannot serve to throw light on the opposing views of the causes of cyclones and anti-cyclones. It is true that the rapid left-hand rotation in the lower air may partly determine the direction of rotation in the air flowing out from the top of a cyclone; but if there is any friction in the air movement this could not extend to the outer limit of a cyclone which depended on difference of temperature within its own field for maintenance. The left-hand rotation near the top might be visible near the centre, but it would soon give way to a right-hand rotation as the air passed toward the edge. I think Ferrel has made this clear by his diagrams and text in his book on "The Winds." If the left-hand rotation did extend to the outer limits of the cyclone then I should consider it evidence that the cyclone was maintained by forces, or wind velocities, originating outside its own field; and hence was what I have called dynamic in its origin. I admit that my diagram does not show this well enough to settle this point, but the most important conclusion to which my diagrams led me Prof. Davis does not mention; and that is that the inward tendency of the air over anti-cyclones shows that the anti-cyclone is due in part or entirely to low temperature, which causes an increase of density and pressure in the lower air, and a decrease above. This is diametrically opposed to the views arrived at by Hann from his mountain observations, and it may be possible to explain these air motions in another way. But, if I am correct in my interpretation of them, we have the theory that the wandering anti-cyclones of the northern hemisphere are mainly due to the low temperature of the air composing them, while the cyclones are originated and largely maintained by dynamic action due to the air forced into them by the surrounding anti-cyclones. This is directly the opposite of the theory elaborated by Ferrel which supposes the cyclone to be due to high temperature, and the anti-cyclone a secondary phenomenon originating by the

action of two or more cyclones. It also differs from the theory of Hann which supposes both cyclone and anti-cyclone to be dynamic in origin. To this should be added another hypothesis maintained by Dr. Veeder, which seems to me plausible, and that is that cyclones receive energy from the sun immediately after and almost coincident with changes in energy on that body, so that sudden outbursts of storms may be connected with sudden changes on the sun, — a view which I infer is sustained by Prof. Bigelow's researches.

The determination of how much each of these hypotheses are true or false furnishes an interesting field of research for the future investigator.

H. H. CLAYTON.

READVILLE, MASS., Sept., 1893.

SIX AND SEVEN DAY WEATHER PERIODS.

Editor of the American Meteorological Journal:

In Prof. Bigelow's article in the September JOURNAL on "The Periodic Terms in Meteorology due to the Rotation of the Sun on its Axis," he says that the chief maxima occur on the 3d, 11th, 17th, and 22d, forming the real basis of the six and seven day cycles, — pointed out by me in the May JOURNAL.

In this conclusion, however, he is clearly mistaken. In the first place I showed in this JOURNAL for August, 1885, that the seven day period was not the result of weather conditions acting simultaneously all over the United States, as in Prof. Bigelow's period; but was the result of barometric waves, or storms, passing across the United States from east to west at regular intervals. But my recent investigations furnish even more convincing evidence against his conclusion.

Soon after writing the article published in the May JOURNAL, I sought to ascertain, by means of averaging, whether the six and seven day periods had persistent lengths, or were set in operation by some meridian of the sun, and disappeared after a time to give place to another set having the same cause, but independent in phase from the first. Neither six nor seven days exactly divide the time of a solar axial rotation. Hence if new periods of these lengths were started at the end of one, or several rotations, they would not be at exactly equal multiples of about six or seven days from preceding periods of this length. So that if persistent periods of the same length were assumed, the different phases would neutralize each other in the average and nothing would be found.

It was shown in the May JOURNAL that periodic oscillations in the temperature of about six or seven days frequently persist for many weeks at a time; and it has been found from a study of the barometric minima recorded at Blue Hill during the last nine years that the most probable length of the seven day period is near seven days six and four-tenths hours, and of the six day period near six days four hours. Consequently the entire nine years of observation were divided up into periods of these lengths; and the frequency of barometric minima on each day of both periods counted up.

The days of maximum frequency were the same for almost every year, and in groups of three years the constant position of the days of maximum frequency is very distinct as shown by the following tables : —

TABLE I.

THE NUMBER OF BAROMETRIC MINIMA AT BLUE HILL ON EACH DAY OF THE SEVEN-DAY PERIOD.

	1.	2.	3.	4.	5.	6.	7.
1885–87	43	38	47	**48**	40	43	**44**
1888–90	44	37	30	**44**	44	25	**50**
1891–93	34	19	31	**46**	35	35	**39**
Total.........	121	94	108	**138**	119	103	**133**

TABLE II.

THE NUMBER OF BAROMETRIC MINIMA AT BLUE HILL ON EACH DAY OF THE SIX-DAY PERIOD.

	1.	2.	3.	4.	5.	6.
1885–87	34	**55**	49	40	**53**	53
1888–90	43	**52**	45	40	**52**	43
1891–93	35	**40**	37	34	**53**	41
Total................	112	**147**	131	114	**158**	137

It will be seen from these tables, not only that there are persistent periods of six and seven days running through all the years from 1885 to 1893, but that in the average there are two maxima and minima in each period, and not the single well-marked maxima at intervals of six and seven days as shown by Prof. Bigelow's result.

As my results indicated that the six and seven day periods were connected with the passage of storms from west to east across the country, and storms have an average eastward drift of about 15° of longitude a day, the space between the sixty-fifth and seventy-fifth meridian and the fortieth and fiftieth parallels of latitude was divided into three sections of 15° each. Mr. Arthur Sweetland then counted up for me, from the charts of storm tracks in the "United States Weather Review," the number of storms (or barometric minima) passing through each of these sections on each day of the six and seven day periods.

The results are shown in Table III.

TABLE III.

THE NUMBER OF STORMS ON EACH DAY OF THE SIX AND SEVEN DAY PERIODS BETWEEN LATITUDES 40° AND 50° N. — 1886 TO 1892.

Seven Day Period.				Six Day Period.			
Day.	*Lon.* 90°-105°.	*Lon.* 75°-90°.	*Lon.* 60°-75°.	Day.	*Lon.* 90°-105°.	*Lon.* 75°-90°.	*Lon.* 60°-75°.
1	53	87	77	**6**	**68**	102	92
2	**66**	86	76	**1**	58	**121**	93
3	52	**98**	77	**2**	**69**	97	**102**
4	49	97	**92**	**3**	59	**103**	93
5	**58**	73	86	**4**	**74**	101	**103**
6	55	**96**	80	**5**	62	101	97
7	56	86	**92**	–	–	–	–

It will be seen that each of these columns shows the same double maxima, and, moreover, there is found a displacement of the maxima by one day for each 15° eastward, corresponding with the average eastward drift of storms.

The barometer readings at Blue Hill at 8 A. M. and 8 P. M. on each day of the six and seven day periods were averaged for 1887 and 1891; and the results corrected for diurnal period (by subtracting .02 from each of the 8 A. M. readings) were as follows: —

Seven-Day Period.

	1.		2.		3.		4.		5.		6.		7.	
	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.
1887......	29.34	29.36	**29.36**	29.33	29.31	29.31	29.31	**29.30**	29.34	**29.35**	29.31	29.28	**29.28**	29.30
1891......	**29.32**	29.32	29.33	29.36	**29.37**	29.33	29.31	**29.30**	29.33	29.36	**29.36**	29.36	29.35	29.35

Six-Day Period.

	1.		2.		3.		4.		5.		6.	
	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.
1887..	29.32	29.29	**29.25**	29.28	29.31	29.32	**29.35**	**29.32**	29.34	29.33	29.33	**29.34**
1891..	29 33	29.33	**29.31**	29.34	29.35	29.36	**29.36**	29.32	**29.31**	29.34	**29.36**	29.34

It will be seen from these results that the barometric minima in the seven day period occur on the third and seventh day and in the six day period on the second and fifth, corresponding closely with the results previously found. However, it was found in the course of the investigation that the more ap-

proximate mean lengths of the periods were 7 days 6.46 hours and 6 days 3.94 hours; and these mean lengths were used in obtaining the results given for the six day period in Table III, and for the barometric means last given.

It might be inferred from the means that the periods should more properly be called three and a half and three day periods; but a study of the individual results leads the writer at present to think the periods are more probably twice these lengths.

A discussion of the individual results will not be entered into here further than to say that it has been found that during intervals of about twenty-seven days, corresponding with a solar rotation, the storm tracks in the United States occur in groups, in each of which the storms all follow the same general direction, and are separated from each other in time by approximately equal intervals of six or seven days, or half these intervals. In many cases it was found that the storms followed each other along such approximately parallel tracks that the irregular bends were the same in all the tracks.

An entire redistribution of the storm tracks takes place at the end of each solar axial rotation and the change in the interval between the storms from a six to a seven day period is likely to take place at the same time though each of these periods frequently lasts through several rotations.

H. H. CLAYTON.

BOSTON, Sept. 20, 1893.

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KATECHISMUS DER METEOROLOGIE.

W. J. VAN BEBBER. *Katechismus der Meteorologie.* Third Edition. J. J. Weber, Leipzig, 1893. 12 mo. 260 pages; 63 figures and charts.

Dr. van Bebber is a member of the staff of the German *Seewarte* at Hamburg, where he is in charge of the daily weather maps and weather forecasts. He has written much on the subject of weather prediction, and has prepared an excellent text-book of meteorology. The little volume here noticed is one of a large series of Illustrated Catechisms, prepared in simple style for popular use. Each paragraph is headed with a question in bold type; and a direct and specific answer immediately follows. The book, therefore, is intended particularly for that class of readers who wish immediate information on one or another division of its subject, without the necessity of studying the subject as a whole. Dr. van Bebber's experience makes him a competent author of such a work of ready reference.

We could wish, however, that more attention had been paid to linking together the different sections of the subject, so that even those who asked for only a part of it might be drawn into seeing the relation of the part to the whole, and thus gain at least some small perception of the beautiful association in which all the phenomena of the atmosphere dwell together. The isolation of facts of local observation is the greatest difficulty that the student of meteorology has to labor against; and this catechism does not do as much as it might to overcome this difficulty. The chapter on the movements of the air, in the middle of the book, appears particularly faulty in this respect, from not describing the circulation of the atmosphere as a whole, and from giving much emphasis to such winds as the foehn and the sirocco, and yet allowing only brief mention of "barometric depressions" and "districts of high pressure." Storms are treated in a special chapter near the end of the book, after the chapter on weather; and from this arrangement the reader would naturally fail to perceive that they are only intense examples of the "barometric minima" already briefly described. Thunderstorms are described in the chapter on electrical and optical phenomena; they might as well or better be placed in the chapter on rainfall. Hail is defined and explained in the chapter on rainfall, and its relation to thunderstorms is not mentioned.

It is perhaps unavoidable that a catechism should retain something of the empirical style by which the older meteorology was so largely characterized; but it is with satisfaction that we can assure our readers that in the statement of fact Dr. van Bebber is truly a representative of the modern school,

and that in this little book he abstracts the facts that he deems most essential from a large store of trustworthy information. The illustrations are simple, but effective; the charts are in larger number than is usual, including Spitaler's Thermal Isanomals and Teisserenc de Bort's lines of equal cloudiness. W. M. D.

FIRST ANNUAL REPORT OF THE SHANGHAI METEOROLOGICAL SOCIETY.

S. CHEVALIER. *First Annual Report of the Shanghai Meteorological Society for the Year* 1892. 8vo. Zi-Ka-Wei, 1893. 50 pages.

THE Shanghai Meteorological Society, whose first annual report is at hand, was formed in 1892, the first meeting being held on Oct. 14 of that year. Its aim, as stated in the provisional regulations, "is to further by study and observations meteorological knowledge in general, but especially the knowledge of the maritime meteorology of Eastern Asia, such as the normal meteorological conditions prevailing along the coast, the law of storms, typhoons, etc." It is open "to every gentleman who is willing to work, either by personally taking meteorological observations and writing on meteorological subjects, or by procuring, with his influential co-operation, meteorological observations or extension of meteorological telegrams, or helping in any way to attain the aim of the society." The Rev. Father S. Chevalier, S. J., director of the Zi-Ka-Wei Observatory, through whose interest the society was organized, is its president.

The first annual report of the society is of considerable interest, not only as showing the present activity of persons interested in meteorology in Shanghai, but also because it promises so well for the future. The report contains a table of the mean, maximum, and minimum values of pressure, temperature, humidity, wind direction and velocity, and rainfall recorded during the year 1892, together with the average mean, maximum, and minimum values of these elements compiled from the previous eighteen years' observations. From this table it is seen that the maximum temperature recorded during 1892 was 102.9° in August, and the minimum 19.4°, in January and December. The greatest rainfall came in May, and measured 6.31 inches. A brief account of the principal typhoons of 1892 follows, illustrated by a chart showing the tracks of these storms.

The Shanghai Meteorological Society, on the suggestion of Father Chevalier, adopted the international nomenclature of clouds recommended by the International Meteorological Congress held at Munich in September, 1891; and in order to familiarize the members and observers with this nomenclature Father Chevalier has prepared a paper on the subject, which, with commendable enterprise, he has illustrated by small reproductions of the cloud photographs in the "Beobachtungen der Meteorologischen Stationen im Koenigreich Bayern" for 1891.

The investigation of the fogs along the northern coast of China forms the subject of the last paper in the report. The observations on which the

conclusions are based were made during 1889–1891, and include barometer and wind records as well as fog records. Father Chevalier has carefully computed the number of foggy days in each month, and the variation of the frequency of fog during the day and with the different states of the barometer. The causes operating to produce fogs are considered, and Father Chevalier believes that the evaporation of warm water under a colder atmosphere has very little to do with the formation of the fogs in China. The main cause of fogs is the cooling of damp or moist air brought from southern regions.

PUBLICATIONS OF THE PRUSSIAN METEOROLOGICAL INSTITUTE.

Owing to the rapid expansion of the Prussian Meteorological System toward the close of the year 1890 an important change in the method of publication of results has been decided upon.

The observations of each of the five divisions of the Institute are to be published separately under the direction of the respective chiefs of divisions.

The five volumes will thus comprise: —

(*a.*) Results of observations at II. and III. order stations. (This will constitute the "*Deutsches Meteorologisches Jahrbuch*" for the Kingdom of Prussia.)

(*b.*) Results of rainfall observations.

(*c.*) Results of thunderstorm observations.

(*d.*) Results of magnetic observations at the Potsdam Observatory. (To begin with the year 1890.)

(*e.*) Results of meteorological observations at the Potsdam Observatory. (To begin with the year 1893.)

In addition to the above the annual report upon the work of the Institute will appear as a separate publication. F.

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